Search For a High-Mass Diphoton State and Limits on Randall-Sundrum Gravitons at CDF

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The paper summaries the CDF search for a high-mass state decaying to two photons. The sample is 202 pb^{-1} of Tevatron data taken at $\sqrt{s} = 1.96$ TeV between February 2002 and September 2004. We examine data with two central ($|\eta| < 1.04$) photons with $E_t > 15$ GeV. We find no significant peaks in the diphoton mass spectrum and set limits on the Randall-Sundrum Model of graviton production. All results are preliminary.

Preliminary Results for Summer 2004 Conferences

Randall-Sundrum Gravitons

I. INTRODUCTION

Searches for new particles decaying to two identical particles are broad, inclusive and sensitive. The production of the new particle may be direct or with associated particles, or in a decay chain. The discovery of a sharp mass peak over background would be compelling evidence of a new particle. The diphoton final state is important because the photons are bosons and the parent maybe fermiphobic. The photons have moderate signal–to–noise but good efficiency and mass peak resolution.

One model producing a diphoton mass peak is Randall-Sundrum gravitons [1]. Current string theory proposes that as many as seven new dimensions may exist and the geometry of these extra dimensions are responsible for why gravity is so weak. The Randall–Sundrum model has the property that a parameter, the warp factor, determines the curvature of the extra dimensions and therefore the mass of the Kaluza–Klien graviton resonances. In this case the resonances are narrow, smaller than our detector resolution, and decay to two bodies including two photons.

Searches in the final state with two electrons, muons, or jets are also being performed. The CDF detector is described in detail in [2].

II. DATA SAMPLE & EVENT SELECTION

Our sample is 202 pb^{-1} of Tevatron data taken at $\sqrt{s} = 1.96$ TeV between February 2002 and September 2004. The data was collected using 4 triggers. The most restrictive cuts come at level 3 where the diphoton triggers require two clusters, isolated in the calorimeter, with $E_t > 12$ or two clusters with $E_t > 18$ regardless of isolation. The high-E_t inclusive triggers are $E_t >$50 GeV with no isolation requirement, or $E_t >$70 GeV with no other requirements at all. The trigger combination would be 100% effective for a high-mass state.

We require that the data was taken under good detector conditions. There must be an event vertex with $|z| <$60 cm, which is 95% efficient. In this analysis, we examine only events where both photons are in the central (approximately $|\eta| < 1.04$) and have $E_t > 15$ GeV and diphoton mass greater than 30 GeV. We require both photons pass standard photon cuts which include good shower shape in the shower max detector, no other significant clusters nearby in the shower max detector, less than 2 GeV of transverse energy in the calorimeter, in a cone of 0.4 around the candidate, and the scalar sum of the P_t of the tracks in the same cone size to be less than 2 GeV.

The final dataset consists of 2001 events. The data histogrammed with bins equivalent to one σ of resolution is shown in Figure 1. The highest mass events occur at masses of 207, 329, and 405 GeV. We have scanned these events and find nothing further of note.

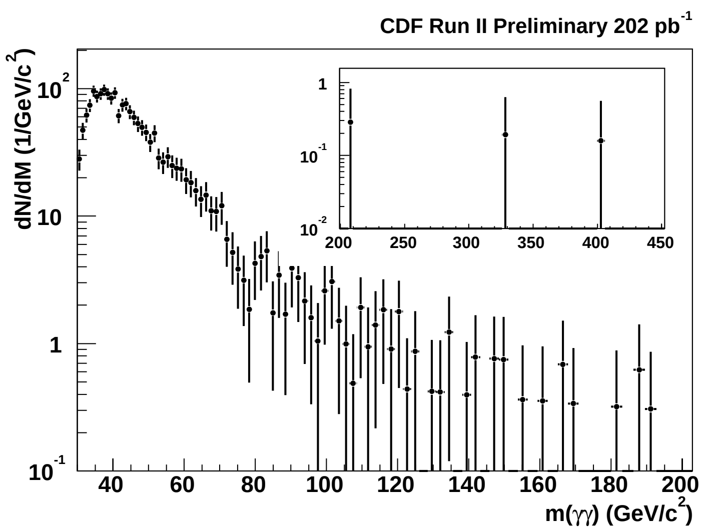

FIG. 1: The diphoton mass distribution histogrammed in bins of approximately one σ of mass resolution.

III. BACKGROUNDS

There are two significant backgrounds to our sample. The first is Standard Model diphoton production which is about 30% of our events. We estimate this background using a NLO Monte Carlo, diphox [3]. We use this program to produce a cross section as a function of mass. We then correct this spectrum by an efficiency function derived from a Standard Model diphoton sample generated using Pythia [4] and our full GEANT–based detector simulation. The leading systematic uncertainty on this result is one half the difference between the central value of fragmentation scale ($m_{\gamma\gamma}/2$) and an extreme value ($m_{\gamma\gamma} * 2$).

The second background is from jets, primarily jets which fragment into a leading π^0, and pass photon cuts. For a control sample, we loosen several cuts including relaxing the isolation cuts by 50%. We reject events in the signal sample and are left with 3996 events in this "photon sideband" sample. We then fit this sample to a sum of several exponentials to derive the shape in the mass distribution. We then normalize the fakes background to the data between 30 and 100 GeV, after subtracting the estimate from the Standard Model diphotons.

The cuts on the photon sideband are varied and the shape is refit. This is leading systematic on the jet background. The statistical uncertainty is also propagated.

Figure 2 shows the data mass spectrum compared to the prediction.

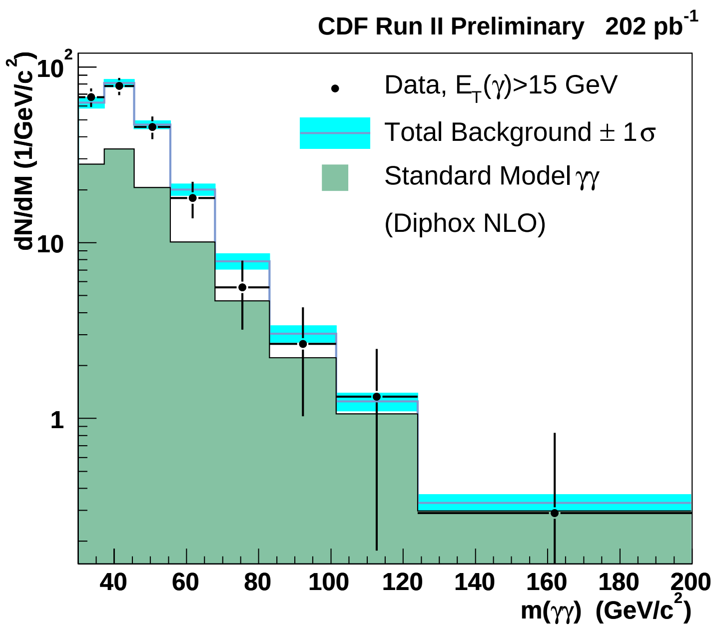

FIG. 2: The observed diphoton mass spectrum compared to the prediction.

IV. EFFICIENCIES

We estimate efficiencies for Randall–Sundrum events with Pythia 6.223[4] and the CTEQ5L PDF. We have reweighted the events for the $\cos\theta^*$ distribution which is not implemented in this version of Pythia. The events are simulated by the full CDF GEANT-based simulation. The acceptance for the central ($|\eta| < 1.04$) and $E_t > 15$ GeV cuts for Randall–Sundrum events is listed in Table I.

Small corrections to the efficiency are derived by comparing data and Monte Carlo detector response to electrons from Z decay. (The electron showers are very similar to photon showers.) We also make a small correction based on detector material studies which are important since material can cause photons to convert and therefore fail cuts.

The final acceptance times efficiency for model events is shown in Table I and Figure 3.

M_G GeV/c^2	Signal Region Range in GeV/c^2	Acceptance	Efficiency*Acceptance
200	184 - 218	0.246 $\pm$ 0.003	0.094 $\pm$ 0.016
250	232 - 272	0.279 $\pm$ 0.003	0.107 $\pm$ 0.017
300	278 - 328	0.313 $\pm$ 0.003	0.121 $\pm$ 0.018
350	324 - 382	0.345 $\pm$ 0.004	0.133 $\pm$ 0.020
400	370 - 434	0.384 $\pm$ 0.005	0.150 $\pm$ 0.023
450	416 - 490	0.421 $\pm$ 0.004	0.168 $\pm$ 0.024
500	460 - 544	0.440 $\pm$ 0.004	0.179 $\pm$ 0.025
550	506 - 598	0.486 $\pm$ 0.005	0.202 $\pm$ 0.028
600	552 - 652	0.495 $\pm$ 0.005	0.201 $\pm$ 0.028
650	596 - 704	0.522 $\pm$ 0.005	0.216 $\pm$ 0.030
700	642 - 758	0.545 $\pm$ 0.005	0.222 $\pm$ 0.031
750	684 - 812	0.553 $\pm$ 0.005	0.220 $\pm$ 0.031
800	732 - 864	0.555 $\pm$ 0.005	0.219 $\pm$ 0.031
850	776 - 916	0.565 $\pm$ 0.006	0.225 $\pm$ 0.032
900	820 - 968	0.562 $\pm$ 0.005	0.225 $\pm$ 0.032

TABLE I: The acceptance for Randall-Sundrum model graviton events decaying to two photons as a function of graviton mass (M_G) in the signal region from Monte Carlo (Pythia 6.223) (statistical errors shown). The right-hand column shows the acceptance times efficiency, which has corrections for data applied (errors shown are statistical and systematic).

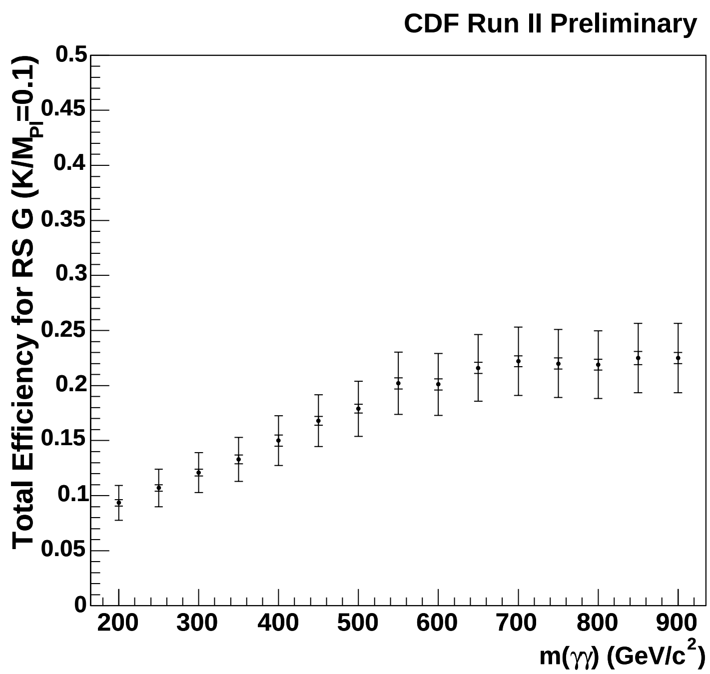

FIG. 3: The total acceptance times efficiency of the Randall-Sundrum model.

V. LIMITS

We perform the limit calculations for a Randall-Sundrum graviton with mass between 200 and 900 GeV. At each point we combine the observed number of events in a 3σ mass window with the background prediction, efficiency, and luminosity in a Bayes style program to compute a limit. We display the cross section limit in Figure 4.

We vary the warp factor and present the limits in two dimensions in Figure 5.

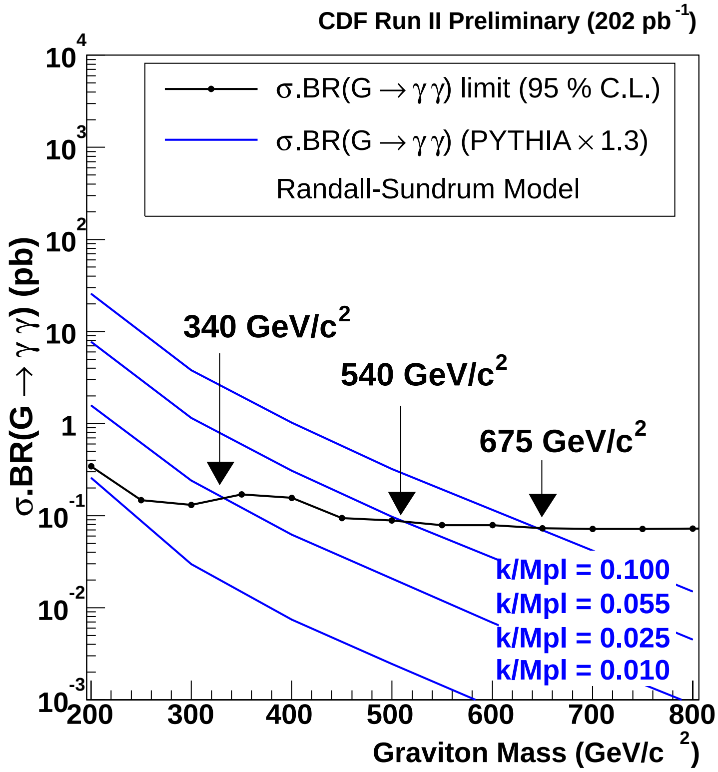

FIG. 4: The cross section limits from the data and the cross section of the Randall-Sundrum Model.

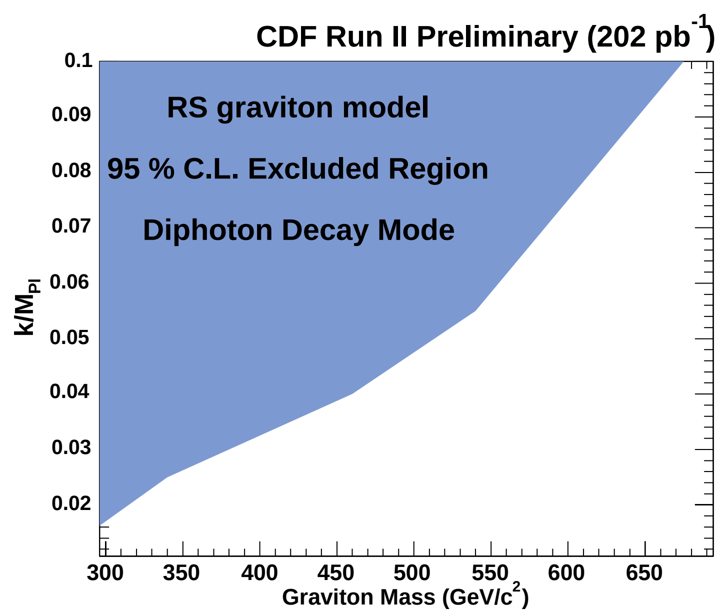

FIG. 5: The limits on the Randall-Sundrum graviton model displayed as a function of graviton mass and warp factor.

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